THE FECAL COLIFORM/FECAL STREPTOCOCCI RATIO AS A MEASURE OF BACTERIAL CONTAMINATION AND INDICATOR OF ITS SOURCE IN THE DES MOINES RIVER

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INTRODUCTION

The greatest problem of polluted water for man has always been the spread of pathogenic bacteria. In 1880, von Fritsch described Klebsiella pneumoniae and K. rhinoscleromatis as microbes characteristic of water contaminated by humans. Escherich identified Bacillus coli (now Escherichia coli) as an indicator of fecal contamination in 1885. At that time water was considered dangerous only when containing human fecal material (Geldreich, 1966). As it is impractical to test water for all potential pathogens, total coliforms have been used as indicators of the potential presence of pathogens. Coliforms are defined as "all aerobic and facultative anaerobic, Gram-negative, nonspore-forming, rod-shaped bacteria that ferment lactose with gas formation with 48 hours of 35°C" (A.P.H.A., 1965). Coliforms include two major groups: (1) Escherichia coli strains which are usually of fecal origin, and (2) Aerobacter aerogenes and intermediate strains which are usually of non-fecal origin. The sources of these organisms in water include: excretions from humans, other mammals, amphibians, and birds; surface runoff contaminated by soil and vegetation; and free-living non-fecal forms in the water itself.

To differentiate between the E. coli and A. aerogenes subgroups, several differential medias have been devised, (such as EMB and Endo agar). The media contain lactose

agars with dyes which impart to a colony a characteristic color dependent upon the pH. The two major groups may be differentiated but problems occur when trying to test and separate the many intermediates. No distinction is made between coliforms of fecal and non-fecal origin using these methods.

Eijkman discovered that coliform bacteria from the intestines of warm-blooded animals would produce gas from glucose broth at 46°C whereas non-fecal strains would not grow (Buras and Kott, 1969). This became the basis for the elevated temperature test used today to separate total coliforms and fecal coliforms (Geldreich, 1966).

The fecal coliform test is highly indicative of warm-blooded animal fecal contamination of water. In studies on the presence of fecal coliforms in soil, Geldreich et al (1962) divided soil types into nine groups (arid, subterranean, submerged, pasture, shore line, woodland, inhabited, cultivated, and polluted). They concluded that the fecal coliforms were relatively insignificant in unpolluted soils even though total coliforms were present in significant numbers in all but arid, subterranean and submerged soils. Similar results were obtained when testing soil mixed with decaying garden vegetation, garden soil free from manure, woodland soil, soil from ungrazed grassland, and soil from protected grassy sites (Medrek and Litsky, 1959). The number of fecal coliforms and fecal streptococci on plants were very low and

were not removed by rainfall and runoff in any significant numbers (Geldreich et al, 1964). The significance of fecal coliforms was shown by Spino (1966) when Salmonella species were consistantly recovered from water samples which showed fecal coliform levels greater than 1000 per 100 ml.

The fecal streptococci (enterococci) have been isolated from man, rats, horses, cows, hogs, chickens, and dogs. The species found in man include Streptococcus faecalis and S. faecium. Species indicative of other animals are S. faecalis var. liquefaciens, S. bovis, and S. equinus (Mundt, 1963). The number of fecal streptococci excreted per animal per day were determined to be (Kenner et al, 1960):

Human	450,000,000
Chicken	619,000,000
Cow	30,680,000,000
Sheep	42,900,000,000
Pig	226,800,000,000

The fecal streptococci are not as viable in surface water as coliforms and do not multiply in water below 10°C (Anon., 1954). They were also found by Mallman and Litzky (1951) to die out rapidly in soil. The streptococci are, however, more resistant to chlorination than are the coliforms (Hajna and Perry, 1943). Because of these differences in viability, it has been recommended to determine fecal streptococci in addition to fecal coliforms (Kabler, 1961; Geldreich, 1966). Differential media have been developed to enumerate the fecal streptococci (Geldreich, 1966; Hajna and Perry, 1943; Kenner, 1960).

Geldreich (1964) has proposed that the fecal coliform/fecal streptococci (FC/FS) ratio in water can show the source of fecal contamination. A ratio of less than 1.0 was found for all warm-blooded animals other than man. The ratio for human contamination was approximately 4.0. Intermediate ratios indicate contamination from both man and animals. Kittrell (1969) has advised that these ratios should not be applied to water more than 24 hours downstream from the bacterial source.

Previous bacteriological work on the Des Moines River has dealt with the isolation and identification of pathogens. DeMoss (1969) isolated Salmonella strains within the city limits of Des Moines, Iowa, and Hoganson (1970) isolated five species of Salmonella from the Des Moines River between Des Moines and Lake Red Rock.

The effectiveness of the FC/FS ratio in a field study over a long period of time where a body of water flows from a rural area, through a metropolitan district, and again to a rural area has not been studied. Under these conditions, a sampling site prior to the entrance of the river into the metropolitan area should show fecal contamination due to agricultural runoff. Upon entering the city, the effects of stormwater runoff and any sewage treatment effluents should be seen. A final site sufficiently downstream from the city should show the effects of a 24 hour water flow and recovery period.

The Des Moines River shows these conditions as it approaches, passes through and continues beyond the city of Des Moines, Iowa. This study was designed to show changes which occur in total coliforms, fecal coliforms, fecal streptococci and the FC/FS ratio as the Des Moines River travels from a rural area, through the city, and into a rural area.

MATERIALS AND METHODS

Sampling Stations

Five main sampling stations were selected on the Des Moines River to show conditions prior to Des Moines, changes which occurred within the city, and recovery upon entering a rural area (Figure 1). The stations were:

Station 1. NW 66th Street (Fisher) bridge located 6 miles north of the Des Moines city limits. This station should presumably show rural conditions.

Station 2. Court Avenue bridge, located in downtown Des Moines and prior to the confluence of the Raccoon River. Major changes at this location should be due to urban runoff.

Station 3. SE 14th Street bridge located 0.8 miles downstream from the entrance of the Raccoon River and prior to receiving the sewage treatment plant effluent. This station should be further indicative of changes produced by an urban area.

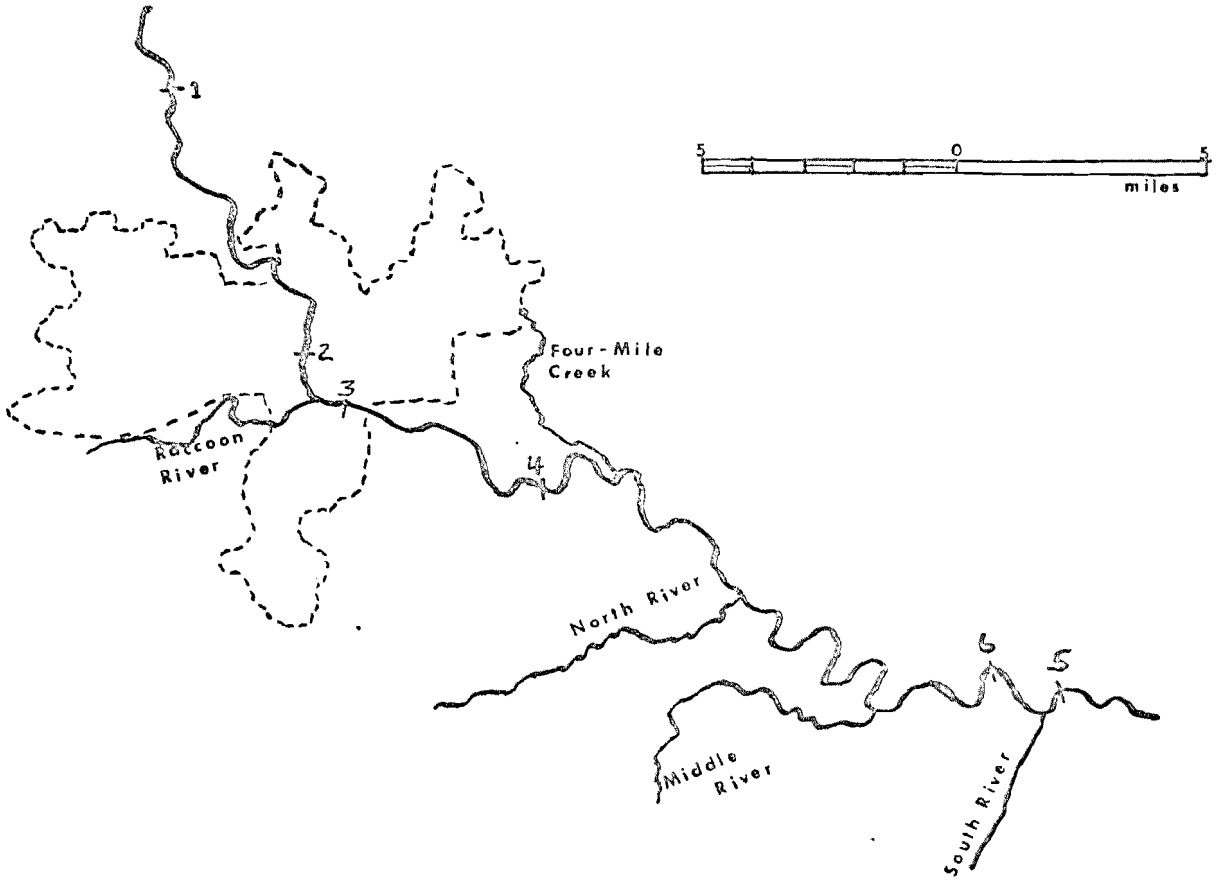

Figure 1. Sampling sites along the Des Moines River.

Station 4. IPALCO bridge on Highway 46 southeast of Des Moines city limits. The Des Moines Sewage Treatment Plant effluent enters the river approximately 0.6 miles upstream from the sampling station. This station should show the influence of the addition of domestic wastes.

Station 5. New Runnell's bridge on State Highway 316, approximately 17 miles downstream from station 4. Tributaries entering the river over this distance are Four-Mile Creek, North River, and Middle River. The South River enters at station 5, but mixing is incomplete and should not affect samples from mid-stream. This station should show changes further downstream from the addition of human sewage and recent exposure to rural runoff.

Station 6. Old Runnell's bridge located 3 miles upstream from the Highway 316 bridge. This site was sampled when accessable prior to the bridge's removal. It was hoped that this station would show conditions prior to the town of Runnells.

Collection of Samples

Samples were collected fortnightly from April 18 to November 14, 1970. Mid-stream samples were taken by lowering a 1200 ml Kemmerer sampler just under the water surface. Samples were normally collected between 10 AM and 2 PM beginning at the northern most station. The water was transferred to two sterile 15 ml screw-top test tubes for

transportation to the laboratory. If any delay occurred before plating, the samples were refrigerated.

Three diurnal studies were conducted at station 4 on June 26-27, October 2-3, and October 30-31 to determine changes in bacterial counts occurring over a twenty-four hour period. Samples were collected at two hour intervals from 10 PM to 8 PM and processed in the same manner as all other samples.

On July 11, additional samples were taken by boat between stations 4 and 6 to determine the effect of tributaries entering the Des Moines River. Samples were taken in mid-stream and at the mouth of each tributary to determine the conditions before mixing.

Laboratory Procedures

Serial dilutions using 9 ml buffered water blanks (A.P.H.A., 1965) were made on each water sample. Each dilution was then drawn through a 47 mm HA type 0.45 μ grid Millipore filter by a vacuum pump and plated as recommended (Geldreich, 1966). Two dilutions were used for all tests (Figure 2).

Total coliforms counts were determined using 10^{-2} and 10^{-3} dilutions. Filters were plated in disposable plastic 47 mm petri plates containing 2 ml M-Endo (Difco) broth on absorbent pads. The plates (enclosed in Whirl-Pak waterproof plastic bags) were inverted in a 37°C waterbath for 24 hours. Enumeration of coliform colonies were done under 10X magnification.

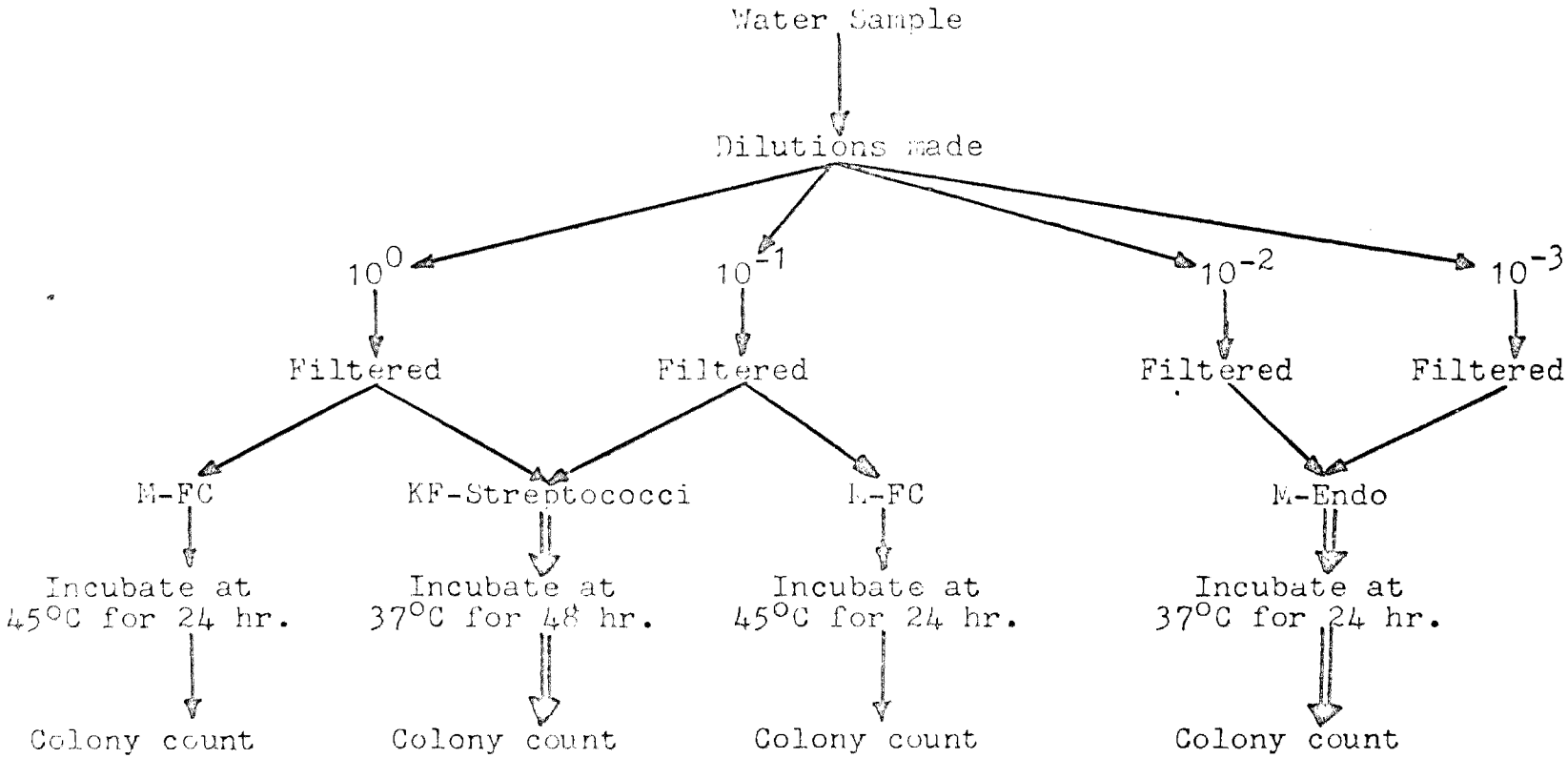

Figure 2. Flow chart for processing water samples, illustrating laboratory procedure for determination of TC, FC, and FS results.

The fecal coliforms were determined with 10^0 and 10^{-1} dilutions by plating on 2 ml M-FC (Difco) broth in the same manner as above. After incubation at 45°C for 24 hours, all blue colonies were counted.

The fecal streptococci dilutions of 10^0 and 10^{-1} were plated on KF-Streptococci (Difco) agar in 47 mm disposable petri plates. These were incubated at 37°C. At the end of 48 hours, all pink colonies were enumerated.

Duplicate tests run on June 27, 1970, showed good correlation in results for the two trials (Table 1).

Chemical data were obtained from other studies being conducted concurrently on the Des Moines River (Gakstatter, 1970; Baumann and Kelman, 1970). Sampling dates did not coincide but conditions within the river system could be determined. Climatological data were obtained from the U.S. Department of Commerce (1970).

Table 1. Results of duplicate tests by group/dilution run on all samples, June 27, 1970.

Station	TC		FC		FS	
	10^2	10^3	10^0	10^1	10^0	10^1
1	>300	>300	0	0	1	0
	>300	>300	0	0	0	0
2	26	10	0	0	0	0
	32	9	0	0	1	0
3	4	1	1	0	5	0
	6	1	0	0	4	1
4	8	1	29	2	2	1
	2	1	23	2	2	0
5	28	2	120	7	3	0
	23	3	143	5	2	0
6	6	0	44	13	10	0
	5	1	52	9	7	1

RESULTS

Bacteriological Data

The total coliform (TC) counts for the five stations ranged from less than 1 X 10^4/100 ml to greater than 9 X 10^7/ 100 ml (all bacterial counts will be reported in number per 100 ml). The mean counts (Table 2) for the stations were 4.5 X 10^6 at station 1, 2.4 X 10^6 at station 2, 2.2 X 10^6 at station 3, 14.0 X 10^6 at station 4, and 2.7 X 10^6 at station 5. Fecal coliform (FC) ranged from less than 1 X 10^2 to 8 X 10^4 for the five stations. The mean counts were, in order, 6.2 X 10^3, 7.9 X 10^3, 6.6 X 10^3, 8.3 X 10^3, and 18.0 X 10^3. The range for fecal streptococci (FS) was from less than 1 X 10^2 to 6.7 X 10^4 with means of 2.4 X 10^3, 2.6 X 10^3, 4.3 X 10^3, 4.3 X 10^3, and 8.1 X 10^3. The ranges for TC, FC, and FS for each of the stations are summarized in Table 3. The mean count for TC was highest at station 4, but those for FC and FS were highest at station 5. Not enough samples were collected at station 6 to produce comparable mean counts.

Seasonal variation was observed at all stations but 4 (Figures 3, 4, 5, and 7). Higher TC, FC, and FS results appeared between June 13 and September 5. Counts decreased in October and November except on October 17 when TC and FC counts increased at all stations except 4. Station 4 showed little seasonal fluctuation with all three groups (Figure 6).

Table 2. Bacterial mean counts (number/100 ml) for each station for the period April 18 - November 14, 1970. TC = total coliform; FC = fecal coliform; and FS = fecal streptococci.

Site	TC	FC	FS
1	4.5×10^6	6.2×10^3	2.4×10^3
2	2.4×10^6	7.9×10^3	2.6×10^3
3	2.2×10^6	6.6×10^3	4.3×10^3
4	14.0×10^6	8.3×10^3	4.3×10^3
5	2.7×10^6	18.0×10^3	8.1×10^3

Table 3. Ranges in bacterial counts (number/100 ml) for the Des Moines River from April 18 to November 14, 1970. TC = total coliforms $\times 10^5$; FC = fecal coliforms $\times 10^3$; and FS = fecal streptococci $\times 10^3$.

Site	TC	FC	FS
1	< .1-300.0	< .1-29.0	< .1-28.0
2	< .1-190.0	< .1-39.0	< .1-22.0
3	.1-250.0	< .1-25.0	.1-41.0
4	< .1-900.0	.5-22.0	.1-40.0
5	.4-210.0	< .1-80.0	< .1-67.0

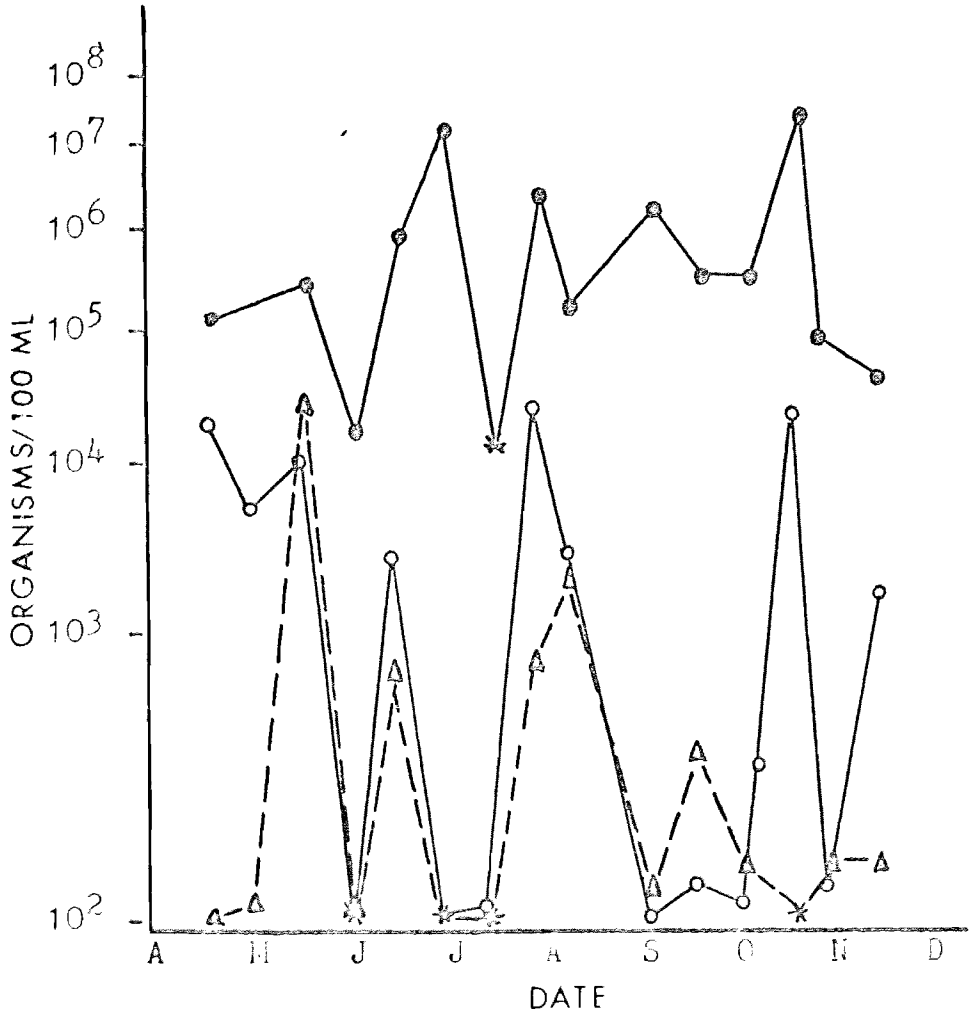

Figure 3. Station 1 (Fisher bridge). Results are expressed in number/100 ml. ⊙ = total coliform; o = fecal coliform; and Δ = fecal streptococci. ✱ = no definite value obtainable.

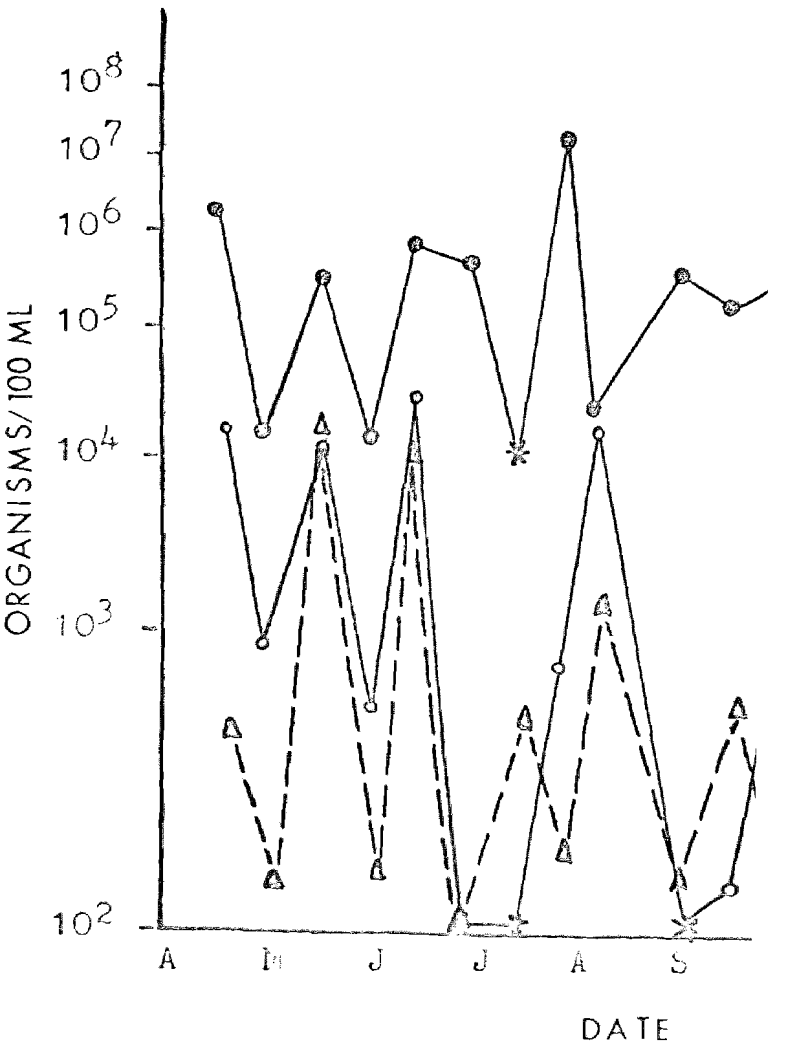

Figure 4. Station 2 (Court Avenue
Results are expressed in number/10
coliform; o = fecal coliform; an
streptococci.
* = no definite value obtainable.

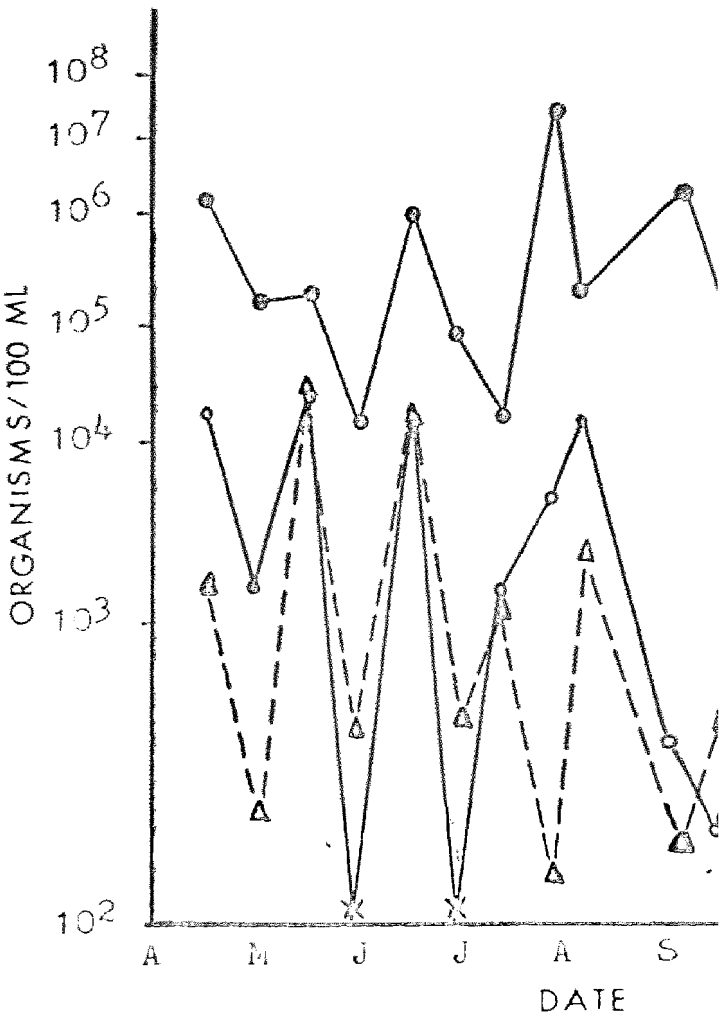

Figure 5. Station 3 (SE 14th St
Results are expressed in number/
coliform; o = fecal coliform;
streptococci.
* = no definite value obtainable

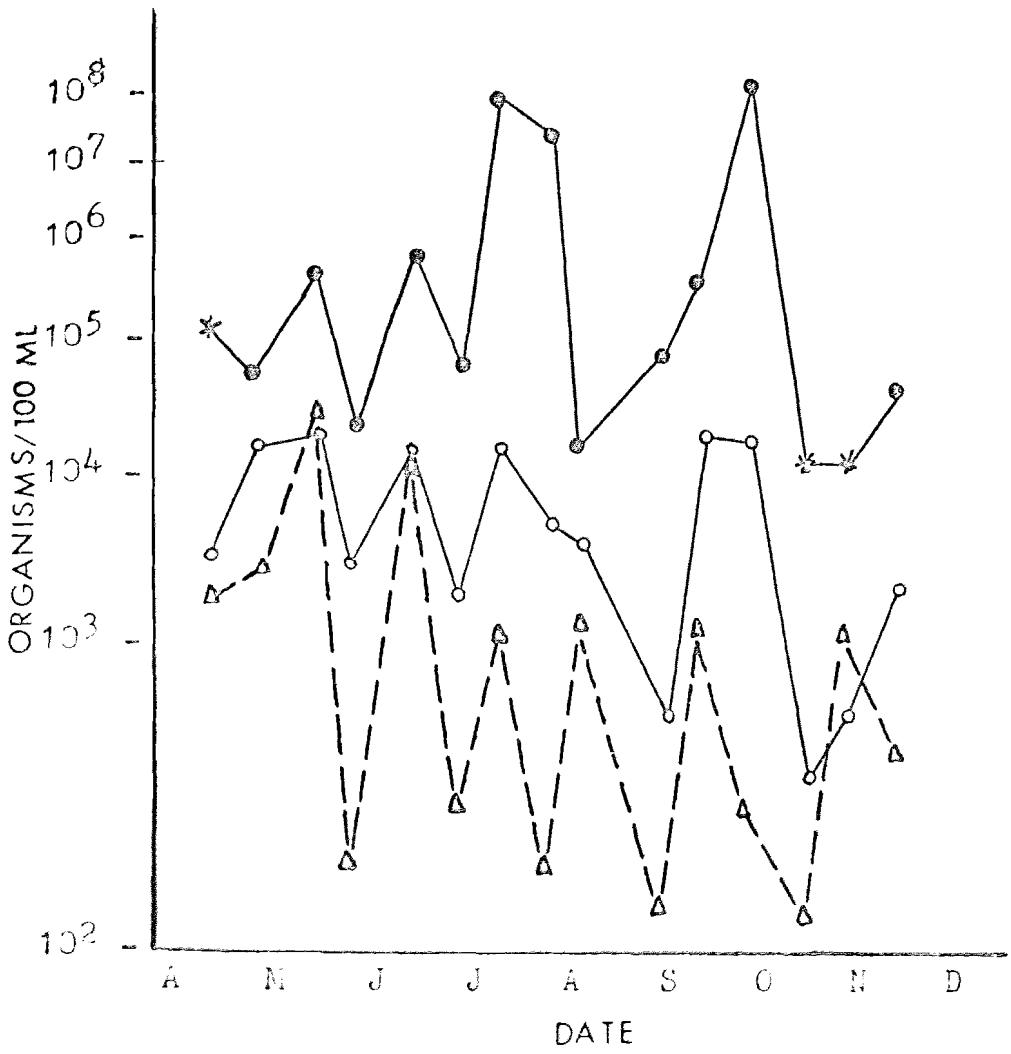

Figure 6. Station 4 (IPALCO bridge). Results are expressed in numbers/100 ml. ● = total coliform; o = fecal coliform; and Δ = fecal streptococci. ✱ = no definite value obtainable.

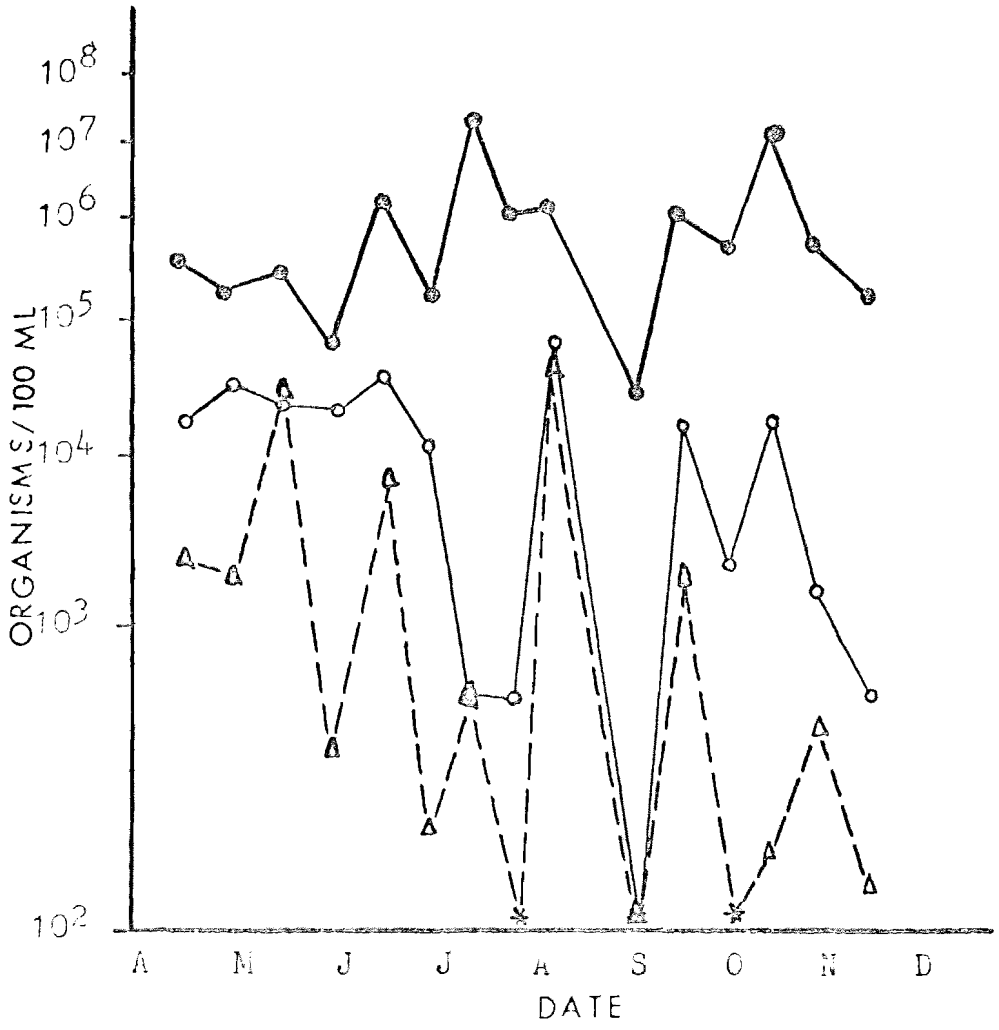

Figure 7. Station 5 (Runnell's Bridge). Results are expressed in number/100 ml. • = total coliform; o = fecal coliform; and Δ = fecal streptococci. * = no definite value obtainable.

The fecal coliform/fecal streptococci (FC/FS) ratio was determined for each sample (Table 4). This ratio was often lower at station 4 than the other stations with the exception of the period from June to September. This can be seen in the mean ratios - 35.06, 16.08, 16.71, 10.74, and 18.83 respectively.

The three diurnal studies at station 4 on June 26-27, October 2-3 and October 30-31 were done to show variation over a twenty-four hour period. Periods of peak counts were seen between 12 and 2 AM and between 6 and 8 PM (Appendices B, C and D). Only during times of high counts were FC numbers greater than FS. This can be seen in the changes in ratios (Table 5 and Figure 8). All counts were significantly higher on October 2-3 than for the other diurnal studies with FC values much greater than the FS (Figures 9, 10, and 11).

The float trip between sites 4 and 5 on July 11 (Figure 12) showed decreasing total coliforms with distance with an exception opposite the mouth of Four-Mile Creek (Table 6). The FC/FS ratio continually increased over this distance. Four-Mile Creek appeared to be the only tributary contributing significantly to bacterial counts in the Des Moines River with values of TC = 5×10^7, FC = 6×10^2, and FS = 1×10^2. North River and Middle River each introduced values of only 2×10^6 for TC, 1×10^2 for FC, and 1×10^2 for FS.

Table 4. Fecal coliform/fecal streptococci ratios for five stations on the Des Moines River, 1970.

Date	Station Number				
	1	2	3	4	5
4/18	-----	23.30	6.90	1.90	3.33
5/2	61.00	9.00	4.00	2.97	20.50
5/17	0.31	0.50	0.69	0.52	0.67
5/30	-----	>65.00	<0.18	23.30	50.00
6/13	4.25	3.25	1.71	1.09	5.68
6/27	-----	-----	<0.17	6.57	38.40
7/11	> 1.00	<0.15	1.27	9.23	1.00
7/25	34.10	4.50	62.00	31.00	>7.00
8/8	1.68	6.67	2.97	3.33	1.19
9/5	< 1.00	< 1.00	2.50	7.00	-----
9/19	0.40	0.14	0.33	12.20	5.71
10/3	1.00	>19.00	6.00	52.50	>30.00
10/17	> 250.00	75.00	150.00	4.80	90.00
10/31	< 1.00	-----	7.00	0.54	3.17
11/14	15.00	1.50	5.00	4.17	7.00

Table 5. Fecal coliform/fecal streptococci ratios for diurnal studies at station 4 (IPALCO bridge), Des Moines River, 1970.

Time	Date		
	6/26-27	10/2-3	10/30-31
10 PM	0.47	168.0	0.86
12 Midnight	1.59	4.9	1.80
2 AM	0.50	24.2	2.50
4 AM	0.23	14.3	3.00
6 AM	< 0.14	87.5	0.57
8 AM	7.50	189.0	0.06
10 AM	4.17	51.5	0.54
12 Noon	1.14	45.4	0.20
2 PM	2.33	1000.0	< 0.50
4 PM	2.08	214.0	0.32
6 PM	7.29	700.0	20.0
8 PM	< 1.00	193.0	3.80

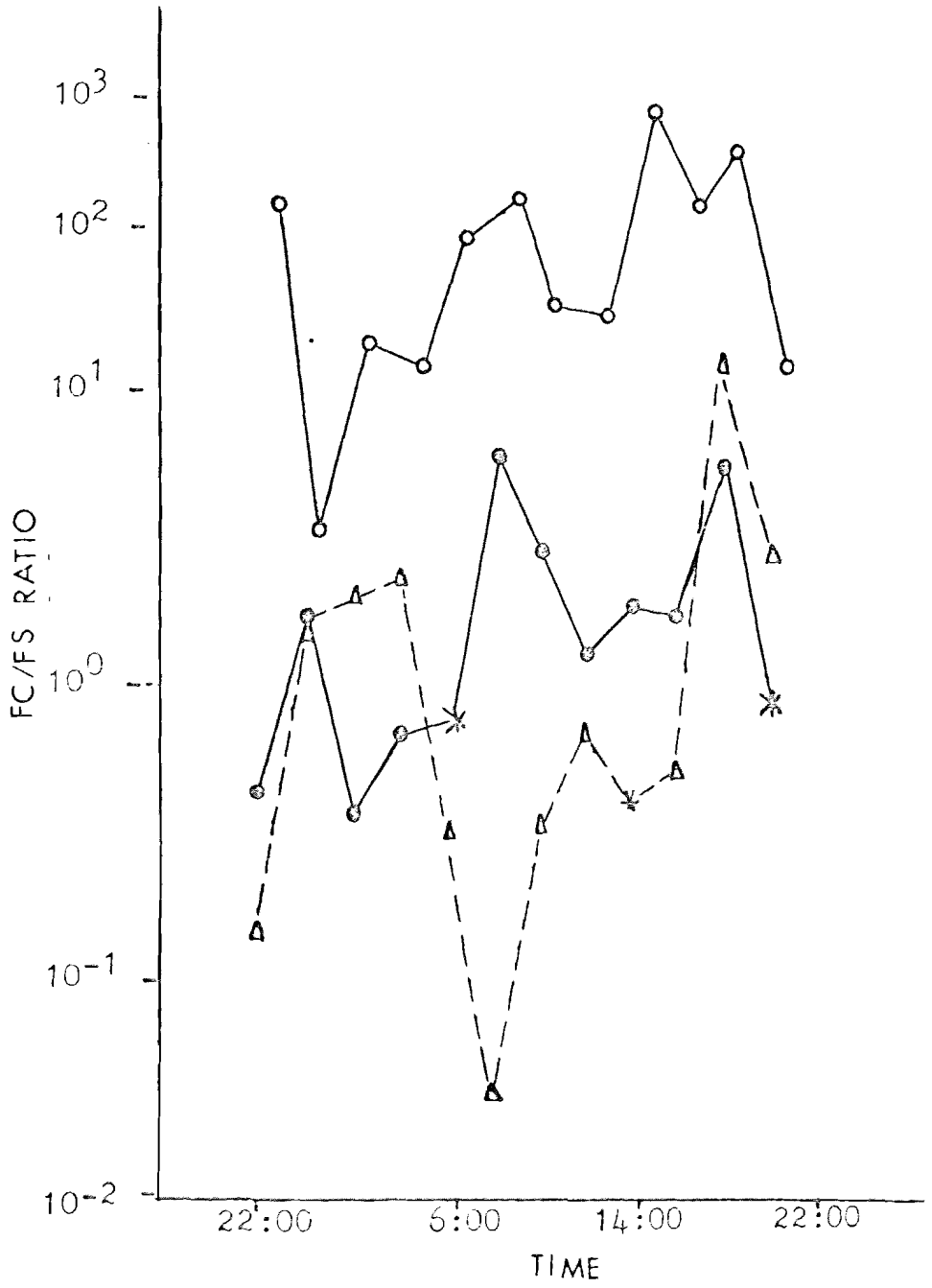

Figure 8. Fecal coliform/fecal streptococci ratios for diurnals at station 4 (IPAICO bridge). • = 6/26-27; o = 10/2-3; and Δ = 10/30-31.
✱ = no definite value obtainable.

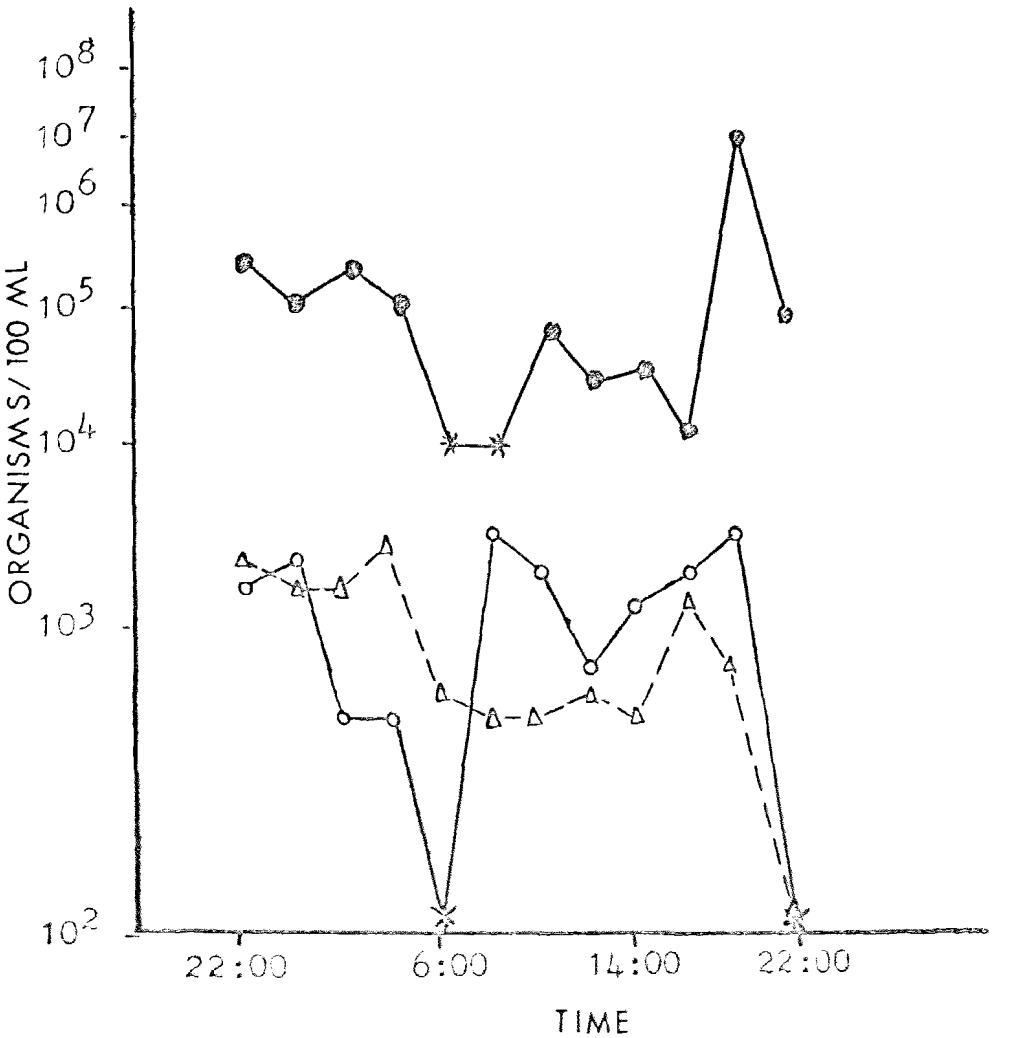

Figure 9. Diurnal at station 4 (IPAICO bridge), June 26-27, 1970. ● = total coliform; o = fecal coliform; and Δ = fecal streptococci.
✱ = no definite value obtainable.

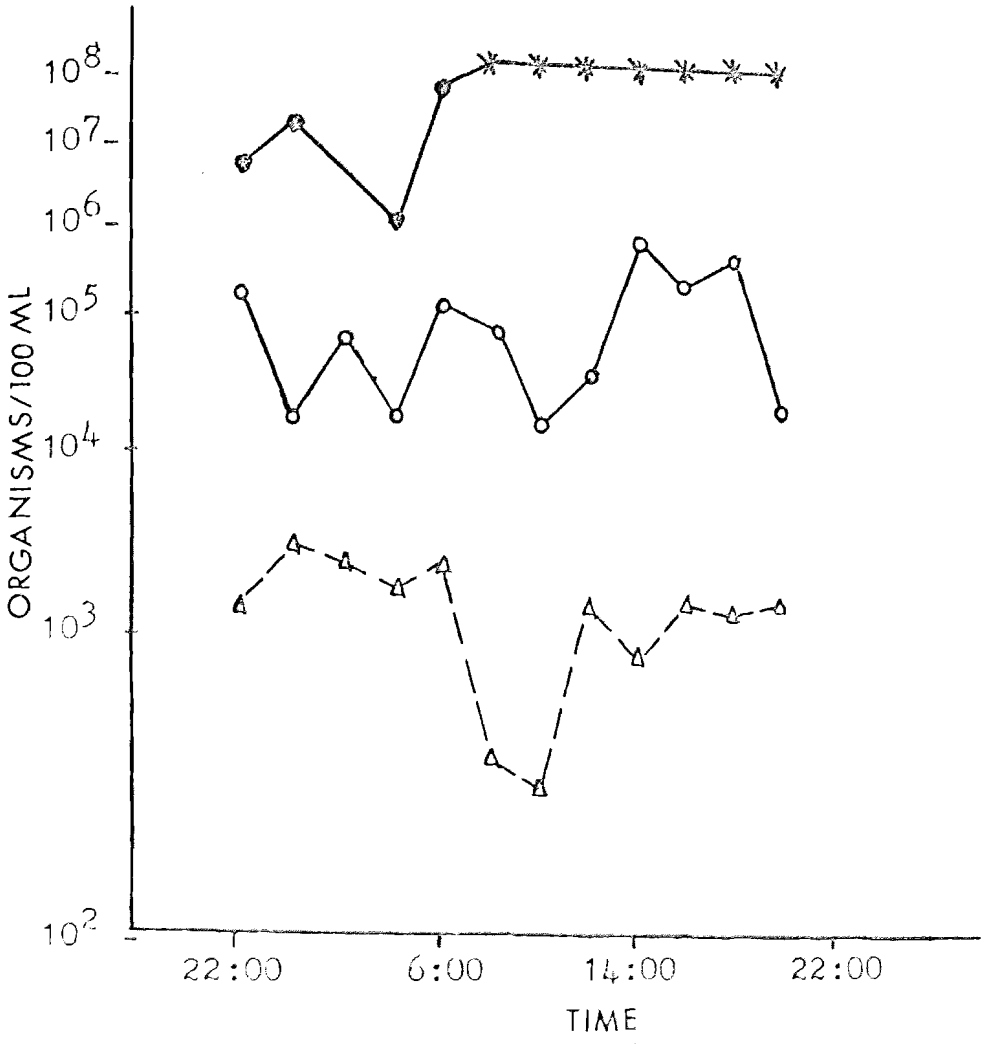

Figure 10. Diurnal at station 4 (IPALCO bridge), October 2-3, 1970. ● = total coliform; o = fecal coliform; and Δ = fecal streptococci.
✳ = no definite value obtainable.

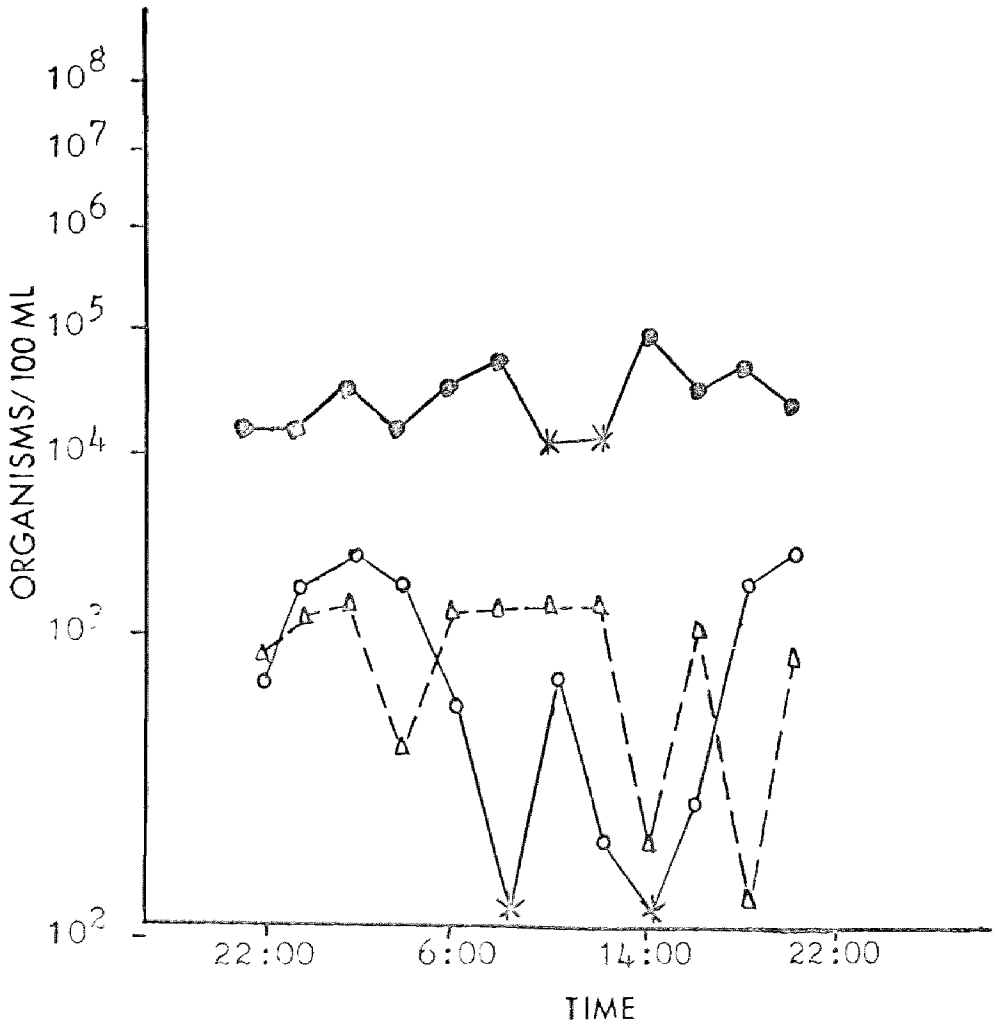

Figure 11. Diurnal at station 4 (IPALCO bridge), October 30-31, 1970. ● = total coliform; o = fecal coliform; and Δ = fecal streptococci.
✱ = no definite value obtainable.

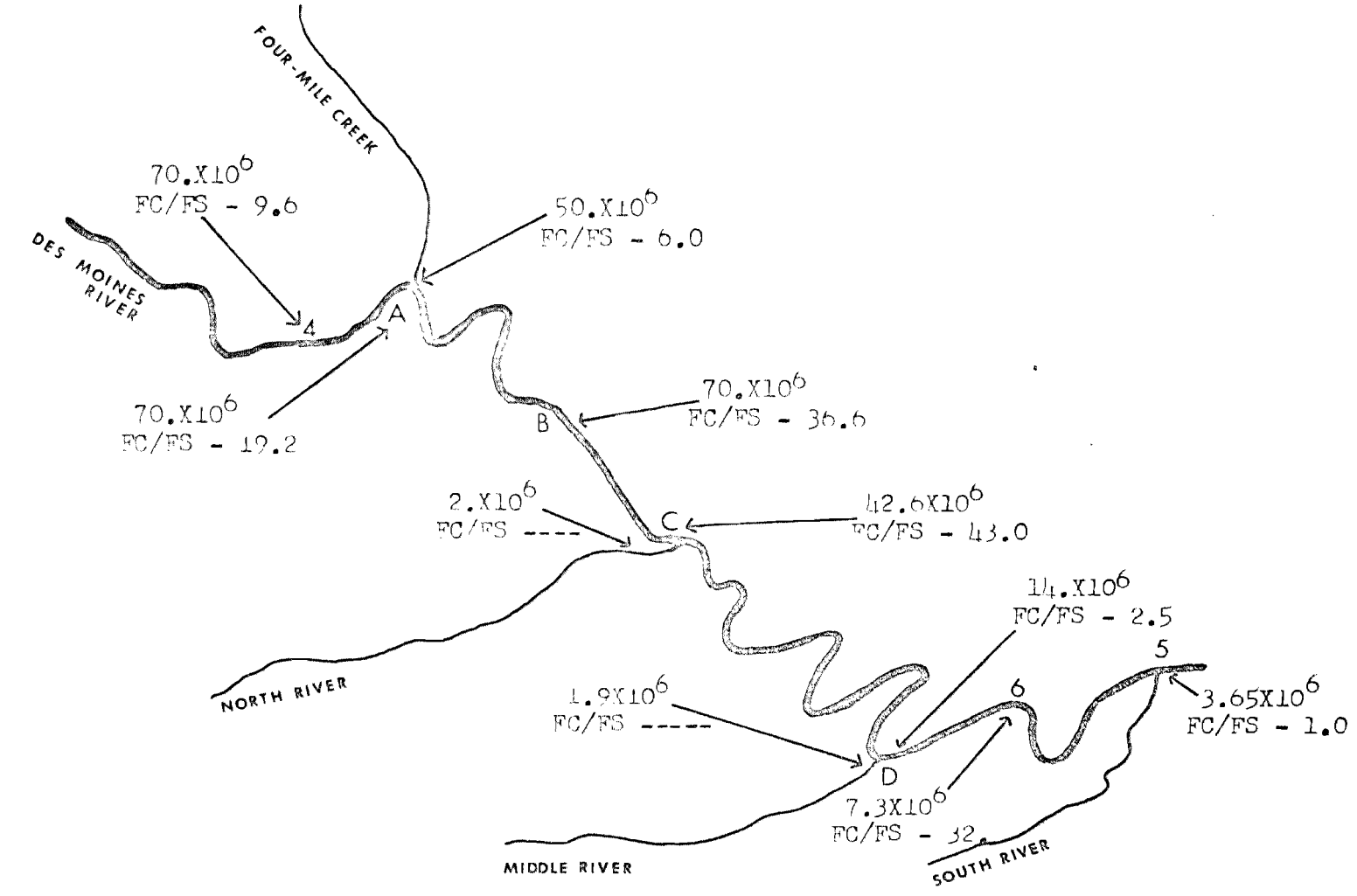

Figure 12. Results of float trip between stations 4 and 5, July 11, 1970, showing TC values and FC/FS ratio. * = no exact value obtainable.

Table 6. Bacterial counts and FC/FS ratio obtained from the float trip between stations 4 and 5, Des Moines River, July 11, 1970.

Site	TC	FC	FS	FC/FS
Station 4	$7.0X10^7$	$1.2X10^4$	$1.3X10^3$	9.6
Four-Mile Creek	$5.0X10^7$	$6.0X10^2$	$<1.0X10^2$	>6.0
Des Moines River A	$7.0X10^7$	$1.2X10^4$	$6.5X10^2$	19.2
Des Moines River B	$7.0X10^7$	$5.5X10^4$	$1.5X10^3$	36.6
North River	$2.0X10^6$	$<1.0X10^2$	$<1.0X10^2$	----
Des Moines River C	$4.3X10^7$	$4.3X10^3$	$1.0X10^2$	43.0
Middle River	$1.9X10^6$	$<1.0X10^2$	$<1.0X10^2$	----
Des Moines River D	$1.4X10^7$	$2.5X10^2$	$<1.0X10^2$	>2.5
Station 6	$7.2X10^6$	$1.6X10^4$	$5.0X10^2$	32.0
Station 5	$2.1X10^7$	$7.0X10^2$	$7.0X10^2$	1.0

Chemical-Physical Data

The chemical data for station 1 was furnished by Iowa State University (Baumann and Kelman, 1970) and that for station 4 by the Iowa State Hygienic Laboratory (Gakstetter, 1970). The sampling dates were not identical nor at equal intervals with Iowa State University sampling weekly and Iowa State Hygienic Laboratory sampling sporadically. The ranges of results for the major factors are given in Table 7. Orthophosphates and pH showed the greatest difference between stations. Station 1 consistantly had higher pH values and lower orthophosphate concentrations than did station 4.

Table 7. Ranges of chemical data for the Des Moines River, April-December, 1970. All results are in mg/l unless otherwise indicated.

	Station 1	Station 4
Temperature (°C)	5.7 - 27.0	3.0 - 25.2
Turbidity	14 - 480 (JTU)	100.0 - 1620 (ppm)
pH	8.00 - 8.90	7.5 - 8.15
DO	5.65 - 16.23	5.4 - 13.9
Nitrate-N	0.01 - 9.10	0.5 - 7.2
Orthophosphate	0.0 - 0.4	0.1 - 1.1
Total solids	421 - 2372	458 - 1639

The amount of precipitation or snow melt was determined (Table 8) for the three days preceeding all sampling dates (U.S. Dept. of Commerce, 1970).

Table 8. Precipitation in inches for the three days preceeding sampling dates, Des Moines, Iowa, 1970. T = trace amounts which could not be measured.

	Days preceeding sampling date			
Date	3	2	1	Total
4/18	.06	---	---	.06
5/2	.09	---	.13	.22
5/17	.22	---	---	.22
5/30	---	---	.04	.04
6/13	.02	.50	.22	.74
6/27	T	.12	T	.13
7/11	---	---	---	---
7/25	---	---	---	---
8/8	.04	.40	1.02	1.46
9/5	---	---	---	---
9/19	.12	.08	---	.20
10/3	---	---	---	---
10/17	---	---	---	---
10/31	T	.02	.05	.07
11/4	.02	.01	.01	.04

DISCUSSION

The total coliform (TC) results showed several basic trends. The mean counts for the five stations showed a gradual decrease from stations 1 to 3, a sharp rise at 4, and a decrease again at 5. This would indicate a death rate greater than the rate of introduction and/or multiplication between stations 1 and 3. The sharp rise at station 4 might be indicative of the introduction of large numbers of organisms or their multiplication between stations 3 and 4. Below station 4 the death rate surpasses that of introduction and multiplication. During the spring, however, station 4 had the lowest TC count with gradually increasing values at stations 6 and 5. Hoskins (1925) showed that coliforms do not multiply as fast in cold stream water, but they survive longer than in warm stream water. This could account for the very gradual, but constant, increase. During the summer and fall, the mean TC counts were highest at station 4, following the same pattern as the mean counts for the total study. This also supports Hoskin's theory for in warmer water the coliforms multiply very rapidly in the water, but are not as viable. The high counts at station 4 would include any coliforms added by the Des Moines Sewage Treatment Plant plus the multiplication of those organisms which entered the river earlier.

This seasonal variation can also be accounted for by water volume and velocity. In low water with slower velocity

many of the bacteria will precipitate out with the sediment (Streeter, 1934). The greater the capabilities of the river to carry its load, the less the chances of bacterial removal by sedimentation.

The float trip between stations 4 and 5 showed changes which occur with low TC input in warm river water. The maximum count was at station 4 and continued at the same level until the North River entered. This can be accounted for by the high TC value in Four-Mile Creek which enters the Des Moines River in this area plus a relatively low die-off rate over this distance (approximately 7.3 miles). From North River to station 5, a gradual decrease in counts occurred as the die-off rate was greater than the number of coliforms being introduced by North and Middle Rivers and the community of Runnells, Iowa.

Changes in TC's were also shown to occur diurnally at station 4. This can be partially accounted for by changes in the sewage effluent at different times of day. During times of peak water usage coliforms present in the sewage trunk lines are greatest; this water upon leaving the treatment plant will also have higher total coliform counts. This could be enhanced by the combined sewage and storm-water runoff trunk lines in Des Moines.

The fecal coliform (FC) and fecal streptococci (FS) appeared to follow identical seasonal trends. During spring and summer, mean counts were higher than those for fall.

The lower counts in the fall could be due to either decreased introduction of these organisms by runoff and tributaries, or decreased survival rates based on water temperature or sedimentation rates.

The float trip showed an increase in both FC and FS values until point B. From there until the Middle River, the counts decreased and then increased slightly as the river passed Runnells. The decline in numbers of organisms present was unequal with FS showing a faster rate of decline. None of the tributaries contributed significant numbers to alter the values of the FC and FS in the Des Moines River. The increase from station 4 to point B would appear therefore to be due to bacterial multiplication and feedlot runoff.

The variation of the FC and FS during the diurnal studies did not appear to follow the variation in TC. These results should be more dependent on how water was used rather than the volume of water being used.

The FC/FS ratio was calculated for all samples in an attempt to determine the source of bacterial contamination. Ideally, one would be able to see an increase in the ratio as the river passed through Des Moines with a subsequent drop following passage into another rural area and a twenty-four hour recovery period. This pattern was observed on July 11, September 5, September 11, and October 3, 1970, however on other dates the ratios followed highly unpredictable patterns. It appears that these ratios are not

applicable under field conditions because of the widely varying conditions. It is possible that the small towns just north of station 1 exert significant influence upon the Des Moines River so that no change could be observed as the river enters Des Moines, and station 1 therefore would not be indicative of a truly rural area. It appeared that the ratio increased mainly in response to a more rapid die-off or sedimentation rate for FS than FC.

There apparently was a positive relationship between rainfall and FS values. There was a less positive relationship with TC counts. Because it has been shown in many studies that soil and subsequently run-off water contain mainly coliforms of non-fecal origin, the result obtained was the opposite of what was expected. This could have been caused by a dilution effect which exceeded the number of organisms introduced.

Hoganson (1970) found a positive correlation between turbidity and coliform values. This was not substantiated in this study possibly due to the difference in dates for the bacteriological and chemical analyses.

The most commonly used total coliform standard for water contact sports is 1000/100 ml with a range of from 50/100 ml to 2400/100 ml (A. S. C. E., 1963). The U.S. Public Health Service standard for non-contact water sports is 5000 TC/100 ml. At no time during this study does the Des Moines River from just north of Des Moines to Runnells

meet the criteria for either contact or non-contact water sports.

Geldreich found the FC/FS ratio highly successful when computed for a dairy effluent, residential sewages, and fecal matter from several sources. It was not found to be an adequate indicator of bacterial source in a river where there was extensive mixing, and greater physical and chemical influences. By running both FC and FS tests in addition to TC determinations, a more complete picture of bacterial content in a body of water was given.

This study has indicated several modifications which might be incorporated into further studies. These include: (1) addition of a sampling site further north of Des Moines, Iowa, in an attempt to eliminate the influence of suburban communities; (2) sampling of all tributaries and major effluents entering the river over the sampling area in an attempt to determine the source of bacterial contamination; and (3) collection of water samples for chemical analysis at the same time as those for bacterial counts. It would be of interest to repeat all or parts of this study following the completion of Saylorville Reservoir north of Des Moines to determine its effect on the water quality of the Des Moines River prior to entering the urban area.

SUMMARY

1. Water samples were collected fortnightly between April 18 and November 14, 1970, from five sites along the Des Moines River and tested for total coliforms (TC), fecal coliforms (FC) and fecal streptococci (FS).

2. The highest mean count for TC occurred at station 4, just downstream from the Des Moines Sewage Treatment Plant effluent and the highest mean values for FC and FS were at station 5.

3. Higher TC, FC, and FS values were found between June and September at all stations except station 4. Spring and fall values were lower.

4. A float trip between stations 4 and 5 on July 11, 1970, showed decreasing TC values with distance, while the FC/FS ratio increased.

5. Three diurnal studies run at station 4 showed that TC, FS, and FC counts had higher values between 12 and 2 AM and between 6 and 8 PM.

6. FC/FS ratios found, in this study, appeared to be dependent upon environmental and physical variations and could not be used as an adequate indicator of bacterial source. It was still believed valid to run both FC and FS counts.

7. More information about the source of bacteria in the Des Moines River might be gathered by monitoring tributaries entering the Des Moines River.

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APPENDICES

Appendix A. Bacterial counts for five stations on the Des Moines River, April 18 - November 14, 1970. All results are in number/100 ml. --- = unable to determine results.

		4/18	5/2	5/17	5/30	6/13
1.	TC	$< 1.0X10^5$	$1.5X10^5$	$3.2X10^4$	$1.0X10^4$	$9.3X10^5$
	FC	$1.4X10^4$	$6.1X10^3$	$8.7X10^3$	$< 1.0X10^2$	$3.4X10^3$
	FS	------	$1.0X10^2$	$2.8X10^4$	$< 1.0X10^2$	$8.0X10^2$
2.	TC	$1.8X10^6$	$1.0X10^4$	$3.3X10^5$	$1.0X10^4$	$8.2X10^5$
	FC	$1.4X10^4$	$9.0X10^2$	$1.1X10^4$	$6.5X10^2$	$3.9X10^4$
	FS	$6.0X10^2$	$1.0X10^2$	$2.2X10^4$	$< 1.0X10^2$	$1.2X10^4$
3.	TC	$1.2X10^6$	$1.2X10^5$	$1.6X10^5$	$1.0X10^4$	$8.7X10^5$
	FC	$1.1X10^4$	$1.2X10^3$	$2.5X10^4$	$< 1.0X10^2$	$2.4X10^4$
	FS	$1.6X10^3$	$3.0X10^2$	$4.1X10^4$	$5.5X10^2$	$1.4X10^4$
4.	TC	$< 1.0X10^5$	$6.0X10^4$	$5.0X10^5$	$2.0X10^4$	$6.8X10^5$
	FC	$4.0X10^3$	$1.1X10^4$	$2.1X10^4$	$3.5X10^3$	$1.2X10^4$
	FS	$2.1X10^3$	$3.7X10^3$	$4.0X10^4$	$1.5X10^2$	$1.1X10^4$
5.	TC	$5.6X10^5$	$2.6X10^5$	$4.0X10^5$	$8.0X10^4$	$1.6X10^6$
	FC	$1.0X10^4$	$4.1X10^4$	$2.4X10^4$	$2.5X10^4$	$4.6X10^4$
	FS	$3.0X10^3$	$2.0X10^3$	$3.6X10^4$	$5.0X10^2$	$8.2X10^3$
6.	TC			$4.4X10^5$	$7.0X10^4$	
	FC			$4.5X10^3$	$6.0X10^3$	
	FS			$4.8X10^4$	$1.2X10^3$	

Appendix A. Continued.

		6/27	7/11	7/25	8/8	9/5
1.	TC	$3.0X10^7$	$<1.0X10^4$	$3.0X10^6$	$1.8X10^5$	$1.1X10^6$
	FC	$<1.0X10^2$	$1.0X10^2$	$2.9X10^4$	$4.2X10^3$	$<1.0X10^2$
	FS	$<1.0X10^2$	$<1.0X10^2$	$8.5X10^2$	$2.5X10^3$	$1.0X10^2$
2.	TC	$6.2X10^5$	$<1.0X10^4$	$1.2X10^7$	$3.0X10^4$	$5.2X10^5$
	FC	$<1.0X10^2$	$<1.0X10^2$	$9.0X10^2$	$1.2X10^4$	$<1.0X10^2$
	FS	$<1.0X10^2$	$6.5X10^2$	$2.0X10^2$	$1.8X10^3$	$1.0X10^2$
3.	TC	$7.5X10^4$	$1.5X10^4$	$2.5X10^7$	$1.8X10^5$	$3.1X10^6$
	FC	$<1.0X10^2$	$1.4X10^3$	$6.2X10^3$	$1.1X10^4$	$5.0X10^2$
	FS	$6.0X10^2$	$1.1X10^3$	$1.0X10^2$	$3.7X10^3$	$2.0X10^2$
4.	TC	$7.5X10^4$	$7.0X10^7$	$3.0X10^7$	$1.0X10^4$	$8.0X10^4$
	FC	$2.3X10^3$	$1.2X10^4$	$6.2X10^3$	$5.0X10^3$	$7.0X10^2$
	FS	$3.5X10^2$	$1.3X10^3$	$2.0X10^2$	$1.5X10^3$	$1.0X10^2$
5.	TC	$2.5X10^5$	$2.1X10^7$	$1.2X10^6$	$1.5X10^6$	$4.0X10^4$
	FC	$9.6X10^3$	$7.0X10^2$	$7.0X10^2$	$8.0X10^4$	$<1.0X10^2$
	FS	$2.5X10^2$	$7.0X10^2$	$1.0X10^2$	$6.7X10^4$	$<1.0X10^2$
6.	TC	$5.2X10^4$	$7.2X10^6$	$4.2X10^6$		
	FC	$7.9X10^3$	$1.6X10^4$	$1.5X10^5$		
	FS	$6.8X10^2$	$5.0X10^2$	$<1.0X10^2$		

Appendix A. Continued.

		9/19	10/3	10/17	10/31	11/13
1.	TC	$5.0X10^5$	$4.8X10^5$	$3.0X10^7$	$8.0X10^4$	$6.0X10^4$
	FC	$2.0X10^2$	$1.0X10^2$	$2.5X10^4$	$<1.0X10^2$	$1.5X10^3$
	FS	$5.0X10^2$	$1.0X10^2$	$<1.0X10^2$	$1.0X10^2$	$1.0X10^2$
2.	TC	$1.7X10^5$	$5.2X10^5$	$1.9X10^7$	$3.0X10^4$	$2.0X10^4$
	FC	$1.0X10^2$	$1.9X10^3$	$7.5X10^3$	$<1.0X10^2$	$3.0X10^2$
	FS	$7.0X10^2$	$<1.0X10^2$	$1.0X10^2$	$<1.0X10^2$	$2.0X10^2$
3.	TC	$9.0X10^4$	$1.0X10^5$	------	$6.5X10^4$	$1.2X10^5$
	FC	$2.0X10^2$	$1.2X10^3$	$1.5X10^4$	$7.0X10^2$	$1.5X10^3$
	FS	$6.0X10^2$	$2.0X10^2$	$1.0X10^2$	$1.0X10^2$	$3.0X10^2$
4.	TC	$5.0X10^5$	$>9.0X10^7$	------	$<1.0X10^4$	$5.0X10^4$
	FC	$2.2X10^4$	$2.1X10^4$	$4.8X10^2$	$7.0X10^2$	$2.5X10^3$
	FS	$1.8X10^3$	$4.0X10^2$	$1.0X10^2$	$1.3X10^3$	$6.0X10^2$
5.	TC	$1.0X10^6$	$7.8X10^5$	$1.1X10^7$	$8.3X10^5$	$3.2X10^5$
	FC	$1.6X10^4$	$3.0X10^3$	$1.8X10^4$	$1.9X10^3$	$7.0X10^2$
	FS	$2.8X10^3$	$<1.0X10^2$	$2.0X10^2$	$6.0X10^2$	$1.0X10^2$
6.	TC					
	FC					
	FS					

Appendix B. Diurnal results for station 4 (IPALCO bridge) on the Des Moines River, June 26-27, 1970. All results are in number/100 ml.

Time	TC	FC	FS
10 PM	3.0×10^5	1.5×10^3	3.2×10^3
12 Midnight	1.9×10^5	3.5×10^3	2.2×10^3
2 AM	3.5×10^5	6.0×10^2	1.2×10^3
4 AM	1.3×10^5	6.0×10^2	2.6×10^3
6 AM	$< 1.0 \times 10^4$	$< 1.0 \times 10^2$	7.0×10^2
8 AM	$< 1.0 \times 10^4$	4.5×10^3	6.0×10^2
10 AM	9.0×10^4	2.5×10^3	6.0×10^2
12 Noon	5.0×10^4	8.0×10^2	7.0×10^2
2 PM	6.0×10^4	1.4×10^3	6.0×10^2
4 PM	1.5×10^4	2.5×10^3	1.2×10^3
6 PM	8.9×10^6	5.1×10^3	7.0×10^2
8 PM	1.2×10^5	$< 1.0 \times 10^2$	1.0×10^2

Appendix C. Diurnal results for station 4 (IPALCO bridge) on the Des Moines River, October 2-3, 1970. All results are in number/100 ml.

Time	TC	FC	FS
10 PM	3.8×10^6	2.1×10^5	1.3×10^3
12 Midnight	1.4×10^7	1.8×10^4	3.6×10^3
2 AM	5.0×10^6	7.5×10^4	3.1×10^3
4 AM	8.7×10^5	2.0×10^4	1.4×10^3
6 AM	$> 5.0 \times 10^7$	2.1×10^5	2.4×10^3
8 AM	$> 9.0 \times 10^7$	9.0×10^4	5.0×10^2
10 AM	$> 9.0 \times 10^7$	2.1×10^4	4.0×10^2
12 Noon	$> 9.0 \times 10^7$	5.0×10^4	1.1×10^3
2 PM	$> 9.0 \times 10^7$	9.0×10^5	9.0×10^2
4 PM	$> 9.0 \times 10^7$	3.0×10^5	1.4×10^3
6 PM	$> 9.0 \times 10^7$	7.0×10^5	1.0×10^3
8 PM	$> 7.0 \times 10^7$	2.9×10^4	1.5×10^3

Appendix D. Diurnal results for station 4 (IPALCO bridge) on the Des Moines River, October 30-31, 1970. All results are in number/100 ml.

Time	TC	FC	FS
10 PM	1.0×10^4	6.0×10^2	7.0×10^2
12 Midnight	1.0×10^4	1.9×10^3	1.1×10^3
2 AM	4.0×10^4	3.8×10^3	1.6×10^3
4 AM	1.0×10^4	1.5×10^3	5.0×10^2
6 AM	4.0×10^4	6.0×10^2	1.1×10^3
8 AM	6.0×10^4	$< 1.0 \times 10^2$	1.6×10^3
10 AM	$< 1.0 \times 10^4$	7.0×10^2	1.3×10^3
12 Noon	$< 1.0 \times 10^4$	2.0×10^2	1.0×10^3
2 PM	8.5×10^4	$< 1.0 \times 10^2$	2.0×10^2
4 PM	4.0×10^4	3.0×10^2	9.5×10^2
6 PM	6.0×10^4	2.0×10^3	1.0×10^2
8 PM	3.0×10^4	3.2×10^3	8.5×10^2